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REPRODUCTIVE BIOLOGY OF CERO, *Scomberomorus regalis*, FROM THE COASTAL WATERS OF SOUTH FLORIDA[1]

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ABSTRACT: Cero, *Scomberomorus regalis*, were collected off south Florida during 1980-81 to determine their reproductive biology. Spawning of cero occurs in coastal waters throughout most of the year with a peak in May. Males attain maturity at about 350 mm FL and females at about 380 mm FL. Fecundity estimates from 20 late maturing or ripe females ranged from 161,000 ova for a 380 mm fish weighing 558 g to 2,234,000 ova for a 800 mm fish weighing 4,944 g. Total weight better indicated fecundity than did fork length. The relationship between fecundity and total weight was expressed by the least square equation $F = -1.079 \times 10^{-1} + (4.342 \times 10^{-4})$ TW. The mean number of ova per gram of fish weight was 362.

Cero, *Scomberomorus regalis*, is probably the least abundant of the mackerel species occurring in United States waters and is primarily caught off south Florida. Jordan and Evermann (1896) give the range of cero as Cape Cod to Brazil including the Gulf of Mexico, but in Florida this species is generally not abundant north of Dade County. Cero is the most frequently encountered mackerel species in the Bahamas (Bohlke and Chaplin, 1968). It is commonly caught in the coastal waters of the West Indies (Collette, 1978), and supports a commercial fishery around Cuba (Howell-Rivero, 1953), the Dominican Republic, Venezuela, and Jamaica (Cooper, 1982). Landing information is not available from American or Caribbean waters, since it is not separated from the landings of king mackerel, *S. cavalla*, and Spanish mackerel, *S. maculatus*. Biological information on cero is limited to general life history and distribution studies (Cervigon, 1966). We report spawning, size and age at maturity, and fecundity for the first time for cero from Florida waters.

METHODS

Cero were sampled in 1980-81 from the recreational hook and line fishery in the Key West area of south Florida. The samples consisted of 247 females and 387 males. All specimens were sexed and measured to the nearest millimeter (mm) in fork length (FL) and to the nearest gram (g) in total weight (TW). Gonads and viscera were removed from each fish, placed in cheesecloth bags, labeled, and then preserved in 10% Formalin. Gonads were later separated from the viscera, trimmed of non-gonadal tissue, blotted dry, and weighed to the closest 0.1 g. Otoliths (sagittae) were removed from specimens selected for fecundity analysis, wiped clean, and stored dry in vials. The otoliths were read for age marks using techniques developed by Johnson *et al.* (1983).

Three methods were used to determine the maturation cycle of cero. The first method determined the developmental stages of gonads by gross examina-

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tion following the criteria of Manooch (1976). Gonads were classified as Stage IS (infantile), Stage I (immature), Stage II (early maturing), Stage III (late maturing), Stage IV (ripe), and Stage V (spent). This technique was useful primarily for males, although it provided some comparative maturation data for females. The second method determined a gonadosomatic index (GSI) which was computed for each fish by dividing the gonad weight by the total weight of the fish and multiplying by 100. The GSIs gave a seasonal maturation pattern from which the range, mean, and 95% confidence interval of the mean were computed. The third method determined the developmental stages of the ova by microscopic examination. For this method, a sample was removed from the midpoint of each ovary. This section was teased apart, to separate the ova of the various stages, and examined under a microscope at 500x for ovum sizes and development. Measurements or descriptions from macroscopic and microscopic methods are shown in Table 1. The microscopic examination was considered the most valuable indicator of female maturity, since this method provided data on ovum stages within the ovary.

Two methods were used to estimate length at maturity for cero. First, all mature fish were grouped by 25 mm (FL) intervals and then the percentages of fish with gonads classified higher than Stage I for each size interval were computed. The size group that first contained 50% or more mature fish was the size at which maturity was estimated to have been attained. Second, cero were grouped by 20 mm (FL) intervals and their mean GSIs were determined. The smaller size group was used because of less GSI variability among the selected fish. The greatest percentage increase in mean GSIs between consecutive size groups was the criterion used for determining size at maturity (Grimes, 1976).

Estimates of fecundity were made with either late maturing or ripe ovaries (Stages III or IV) collected during the months when the fish were reproductively active. Those fish that appeared to be partially spent were not used for this study. Samples were selected randomly from the anterior, middle, and posterior part of one ovarian lobe. A wedge-shaped section containing a portion of the outer, middle, and inner area of the ovary was weighed to the nearest 0.01 g. All yolked ova 0.2 mm or greater in diameter were teased apart and counted under a dissecting microscope. Fecundity was estimated for each fish using the formula

$F = \frac{A}{B} \times C$ where F = fecundity of the fish, A = weight of both ovaries, B = weight of sections, and C = total number of ova in the sections. Regression equations were calculated to determine the relation of fecundity to length and weight of cero and are based on standard Model-I regression techniques (Laws and Archie, 1981). Our fecundity estimates represent all ova 0.2 mm or greater in diameter which we believe are released during the spawning season.

RESULTS

Cero appeared to have a prolonged spawning period that may extend throughout most of the year. Late maturing females (Stage III) were present from March through July and males from January through July (Figs. 1 and 2). Most spawning occurred in April and May for both the males and females, as the mean GSIs peaked in May. Ripe males (Stage IV) were present in February and from April through July. Spent females occurred from January

Table 1. Classification of ova and ovaries used to determine maturation stages of cero, *Scomberomorus regalis*.

	MICROSCOPIC		MACROSCOPIC	
Stage	Size (mm) of largest ova	Appearance of largest ova	Appearance of ovary	Characteristics of individual ova
IS (Infantile)	0.01-0.06	Transparent	Ribbonlike, difficult to sex positively	Not visible
I (Immature)	0.07-0.19	Translucent	Slender, simple to sex positively	Not visible
II (Early maturing)	0.20-0.50	Opaque	Slightly enlarged	Barely visible
III (Late maturing)	0.51-0.70	Opaque with narrow transparent band around perimeter of ovum	Moderately enlarged	Easily visible
IV (Ripe)	0.71≥1.00	Small opaque center, with wide transparent band around perimeter of ovum, and with oil globule(s)	Greatly enlarged and turgid	Easily visible (and easily dislodged from follicles, or loose in lumen)
V (Spent)	0.40≥1.00	In various states of reabsorption or collapse, with ragged appearance	Enlarged but flaccid (somewhat similar to Stages II and III	Barely to easily visible

through May and again in September, November, and December, while spent males occurred from January through April and in December.

Most male cero greater than 350 mm were mature and all females greater than 375 mm were mature (Table 2). The smallest mature male was 336 mm, and the smallest mature female was 370 mm. The largest immature female was 480 mm, and the largest immature male was 459 mm. The greatest percentage increase in mean GSIs indicated that females mature at about 380 mm FL (Table 3).

Fecundity estimates were made for 20 females ranging in size from 380 to 800 mm (Table 4). Counts of ova ranged from about 161,000 to 2,234,000. Regression and correlation analyses showed that total weight was probably a better indication of fecundity than was fork length. The least squares equation for fork length versus fecundity was $F = -1.607 + (4.089 \times 10^{-3})FL$ with $r = 0.86$, and for total weight versus fecundity, it was $F = -1.079 \times 10^{-1} + (4.342 \times 10^{-4})$ TW with $r = 0.92$ (Fig. 3). Fecundity was significantly correlated ($\alpha = 0.01$) with FL and TW. The mean number of ova per gram of fish was 362. The oldest fish used for fecundity

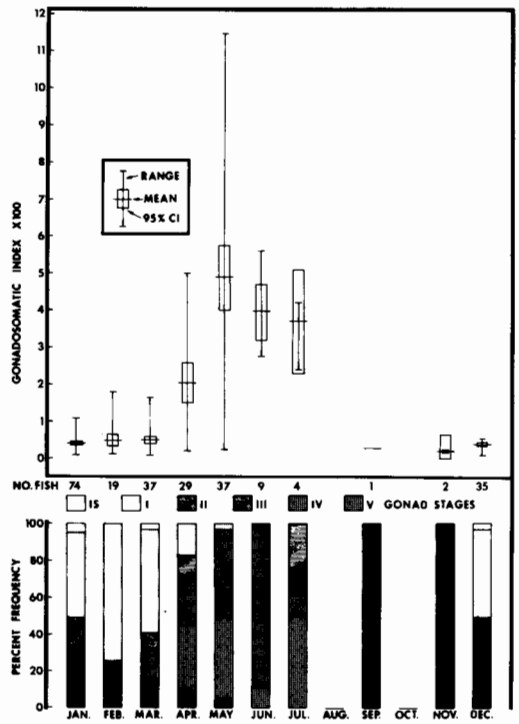

Figure 1. Seasonal maturation cycle of female cero shown by monthly gonadosomatic index (GSI), range, mean, and 95% confidence interval of the mean and gonad stages from infantile to spent (Stages I-S-V).

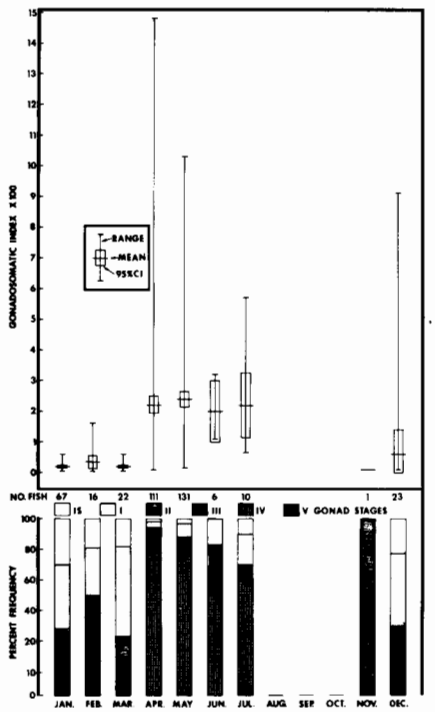

Figure 2. Seasonal maturation cycle of male cero shown by monthly gonadosomatic index (GSI), range, mean, and 95% confidence interval of the mean and gonad stages from infantile to spent (Stages IS-V).

Table 2. Percentages of mature (gonad Stage II through V) cero.

Fork length	Males		Females	
(mm)	No.	%	No.	%
300-324	0	0.0	0	0.0
325-349	2	50.0	0	0.0
350-374	22	61.8	4	25.0
375-399	39	82.0	5	100.0
400-424	60	91.7	11	100.0
425-449	57	96.5	18	100.0
450-474	34	91.2	5	100.0
475-499	19	84.2	5	100.0
500-524	11	90.9	4	100.0
525-549	6	100.0	6	100.0
550-574	5	100.0	5	100.0
575-599	0	0.0	3	100.0
600-624	2	100.0	5	100.0
625-649	1	100.0	4	100.0
650-674	0	0.0	2	100.0
675-699	0	0.0	1	100.0
700-724	0	0.0	0	0.0
725-749	0	0.0	0	0.0
750-774	0	0.0	0	0.0
775-799	0	0.0	0	0.0
800-824	0	0.0	1	100.0
Total	258		79	

Table 3. Changes in mean gonadosomatic indices (GSIs) by 20 mm FL intervals for mature female cero.

Fork length (mm)	No.	GSI (mean)	% increase or decrease
360-379	4	0.36	—
380-399	5	1.88	425.4
400-419	6	4.10	117.7
420-439	15	3.11	-24.1
440-459	11	4.68	50.6
460-479	3	4.41	-5.9
480-499	4	3.54	-19.6
500-519	3	3.54	-0.3
520-539	5	3.87	9.5
540-559	5	3.26	-15.7
560-579	2	2.21	-32.3
580-599	3	2.97	34.3
600-619	3	5.60	88.6
620-639	4	4.24	-24.2
640-659	3	7.57	78.3
660-679	2	4.12	45.6

estimates was 5+ and weighed 4,944 g, while the youngest fish was 1+ and weighed 558 g.

DISCUSSION

The end of the spawning season was not determined, since sampling from August through November was sparse (four fish). Based on the number of Stage IV fish, which increased in July, we believe the majority of fish were sexually mature during most of the period between August and October. Erdman (1976) collected ripe cero in waters off Puerto Rico during May and June and juveniles during July and August. He believed cero spawned virtually all year.

We were unable to determine the duration or frequency of spawning, but it may be similar to the spawning cycle of Atlantic coast Spanish mackerel

Table 4. Summary of fecundity data for 20 cero.

Collection date 1980-81	Fork length (mm)	Total weight (g)	Gonad weight (g)	Fecundity estimates
6-09-81	380	558	20.1	161,206
5-23-80	400	567	37.8	165,070
5-23-80	431	734	57.6	215,829
5-24-80	441	794	73.6	495,209
5-09-81	450	908	33.9	243,344
5-23-80	451	849	48.4	185,394
5-01-81	454	650	39.0	398,128
6-01-81	480	908	44.6	443,793
4-25-81	480	908	28.6	187,023
6-17-81	500	1,178	42.2	289,793
6-17-81	525	1,362	47.5	328,972
5-06-81	540	1,589	67.8	494,237
4-27-81	555	1,632	62.6	248,297
5-14-81	560	1,816	137.6	941,850
7-04-80	570	1,530	64.1	457,344
6-17-81	580	1,686	83.1	903,248
5-14-81	610	2,270	116.0	623,020
5-15-81	625	2,270	137.5	965,383
4-21-81	675	2,724	136.1	835,856
5-14-81	800	4,944	308.6	2,233,815

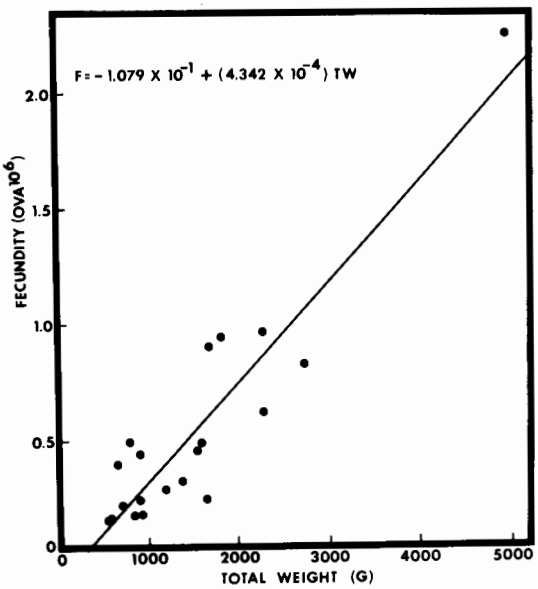

Figure 3. Regression of fecundity on total weight for cero off south Florida.

where Earll (1883) reported that spawning may last 6 to 10 weeks in any one area. Cero appear to be multiple spawners, because at least three oocyte size groups (Stages II, III, and IV) are present in the ovaries during the spawning season.

The spawning area for cero is still unknown. The presence of ripe fish in coastal waters suggests that spawning probably occurs over the inner continental shelf. Spawning of mackerel in the northwestern Gulf of Mexico as inferred from larval abundance, indicates that Spanish mackerel spawn over the inner continental shelf while king mackerel spawn over the middle and outer continental shelf (McEachran *et al.*, 1980).

Some descriptions of ova of cero are available from laboratory rearing experiments by Mayo (1973) who stated that the ova ranged from 1.16 to 1.22 mm in diameter and were covered with large dense chromatophores. Ripe preserved ova from our fish measured about 1.30 mm and had a single oil globule about 0.35 mm in diameter. These ova are larger than Spanish or king mackerel ova.

Size at maturity for cero was greater than that for the Spanish mackerel observed by Klima (1959). He reported the shortest female to be 25 cm FL and the largest immature female to be 32 cm. The shortest male was 28 cm and the longest immature male was 39 cm. Powell (1975) found Age I female Spanish mackerel to have ripe oocytes, which agrees with our estimated age of maturity for cero. He suggests that these fish do not contribute significantly to spawning because many of this age have regressing ovaries.

Of the three maturation methods used in this study we considered our microtechnique as the best indicator of sexual maturation. The GSI values have been shown by DeVlaming *et al.*, (1982) to be more variable in determining when fish will spawn. They believe histological examination or the determination of oocyte diameters are the best means of assessing gonad maturation.

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